Evaluation of Existing NPS Flood Preparedness Plan and Recommendations for the Integration of an Automated Early Warning System

Hot Springs National Park
Hot Springs, Arkansas

January 1993

Prepared by:
Lex A. Kamstra, Surface Water Branch
Patricia Hagan-Chagnon, Operations & Maintenance Engineering Branch
Bureau of Reclamation
Denver Office

Table of Contents

Tables

Figures

Executive Summary

An evaluation of the existing Hot Springs NPS Flood Preparedness Plan, which included an analysis of integrating an Early Warning System (EWS) has inspired the following recommendations:

A precipitation-monitoring EWS is highly recommended for the Central Avenue/Bathhouse Row area, since it is subject to flash flooding on a relatively frequent basis and visited year round by a large number of tourists. The EWS would give from 10 to 120 minutes of additional warning time and be integrated into the NPS Flood Preparedness Plan. The EWS presented in Alternative A is the recommended EWS, since it provides the most advantages for detecting floods and warning the population at risk. Table 4 shows a cost summary for Alternative A. The EWS would be incorporated into the Corps of Engineers future flood control project to provide flood warnings for a wide range of flood magnitudes.

Revisions to the NPS Flood Preparedness Plan with respect to monitoring, notification, training/exercise, coordination, and review are recommended. Specific comments are listed within this report which will improve the existing NPS Flood Preparedness Plan

The use of mitigation strategies, such as blocking roads, outdoor warning systems, public awareness programs, warning-evacuation-rescue plan, long-term implementation task force, and National Flood Insurance Program are recommended to enhance flood warning operations for Hot Springs National Park and the City of Hot Springs, Arkansas.

I. Introduction:

An examination and evaluation of the existing National Park Service (NPS) Flood Preparedness Plan for Hot Springs Creek at Hot Springs National Park was requested by Mr. Charles Karpowicz, Engineering and Safety Services Division, NPS, Washington, D.C. A field examination of the Hot Springs Creek system was completed on August 5, 1993 by Bob Swain, Patricia Hagan-Chagnon, and John Steighner of the Bureau of Reclamation.

II. Purpose:

This report evaluates the flood warning operations for Hot Springs Creek at Hot Springs National Park, Arkansas and recommends enhancements that should be made in order to insure the safety of future visitors and limit the liabilities of the NPS.

III. Description of Existing Conditions:

A. Study Location:

Study location and drainage boundary maps are shown on figures 1 and 2. Hot Springs Creek originates in a small valley (approximately 3.5 square miles) that lies between Sugarloaf, West, and Hot Springs Mountains. Hot Springs Creek drains the eastern one-third of this valley and Whittington Creek drains the remaining two-thirds of the valley to the west. The only hydraulic outlet is a narrow, 300-foot-wide gorge between West and Hot Springs Mountains. Hot Springs Creek and Whittington Creek each enter arch tunnels before they converge underground and become Hot Springs Creek. The NPS Bathhouse Row and the historic central business district are located in this narrow gorge which further reduces its width. The 100+ year-old arch tunnel continues underground through the narrow gorge and the central business district for approximately 3,800 feet and then becomes an open channel. Hot Springs Creek continues to flow in an open channel until its confluence with Lake Hamilton three miles downstream.

B. Previous Flooding:

i. Principal Flooding Problems: Hot Springs and Whittington Creek have small-steep drainage areas which produce rapid runoff flows. Limited stream capacities have caused flooding problems along the entire reach of both streams. The most hazardous flooding condition exists along the arch-tunnel which flows beneath the main business district of Hot Springs. The arch-tunnel constricts flow capacity to an estimated one year return period. Flows which exceed the tunnel capacity spill onto city streets and become hazardous if they are significant. Historically, the tunnel capacities for Hot Springs and Whittington Creek have been exceeded almost yearly and hazardous flooding has occurred six times since 1923.

ii. **Historical Flooding:** There have been six hazardous floods recorded in the past 70 years (1923, 1956, 1963, 1982, 1985, and 1990), and of those floods, five have occurred in the past 37 years. The most recent damaging flood was in 1990. The largest flood of record was in 1923. All of the storms produced extensive flooding with depths from 4 to 9 feet and flow velocities up to 15 ft^3/s along Central Avenue. Three people have lost their lives in past floods and the economical losses have been in the millions of dollars. The 1974 Flood Plain Information Report gives a good indication of the flash flood condition that exists along Hot Springs Creek. The report calculates a rate of rise of 8.4 ft/hr for the intermediate regional flood and 7.4 ft/hr for the standard project flood (SPF). Table 1 gives a summary of the High-water-marks along Hot Springs Creek and Whittington Creek for the May 19-20, 1990 flood.

iii. **Previous Studies:** Previous studies investigating the flooding of Hot Springs Creek include the following:

- Flood Plain Information Report, June 1974, Corps of Engineers.
- Flood Insurance Study, June 1979, Corps of Engineers.
- Flood Control Reconnaissance Study, May 1990, Corps of Engineers.
- Initial Project Management Plan, Flood Control Study, Ouachita River Basin, Hot Springs, Arkansas, April 1991, Corps of Engineers.
-Flood of May 19-20, 1990, in the Vicinity of Hot Springs, Arkansas, 1992, U.S. Geological Survey

The 1990 Reconnaissance Study calculated floods for the 1-,2-,5-,10-,25-,50-,100- ,500-year and SPF frequencies. The computed flood profiles along Whittington Creek and Hot Springs Creek are presented on figures 4,5, and 6 (refer to Figures 1 and 2 for stationing location). Flooding is indicated for all frequencies, which is realistic since the capacity of Hot Springs Creek tunnel has an approximate one year return period. However, it is documented that the flood depths shown for the 1, 2, and 5 year floods are overestimated and the Corps of Engineers HEC-1 model should only be used to simulate floods greater than 10 years return interval.

C. Existing Flood Warning Operations:

i. **Potential Population at Risk:** Based on figures received from the National Park Service, the number of tourists visiting Hot Springs National Park was approximately 316,840 for FY 92, and 320,431 for FY 93. Although these numbers do not reflect the number of people that would be on Central Avenue/Bathhouse Row at one particular time, they can be used to give a general idea of the potential population at risk. The peak months are June, July, and August.

ii. **Flood Warning Preparedness Plan:** The NPS Flood Preparedness Plan for Central Avenue/Bathhouse Row was prepared January 1990. It was written to provide an established action plan to handle any flood situation which may occur.

According to the Flood Preparedness Plan, a notice of flood danger has been divided into three stages. In Stage 1, the Ranger Division monitors the flood watches and warnings

issued by the National Weather Service and notifies the Chief Ranger, Superintendent, and Assistant Superintendent. Stage II is initiated when 2 inches of rain in any 12-hour period has fallen. During Stage 2 the patrol ranger will ascertain the condition of the flood waters in Whittington Creek and Hot Springs Creek. In the event the water in either creek rises within one foot of the top of its tunnel entrance, and additional rainfall is occurring, a notification process is initiated. The Chief Ranger, Superintendent, Assistant Superintendent, Facility Manager, City Policy Department, and Bathhouse Row concessionaires are notified in this process. If the water fills the arch, and rainfall is continuing, the patrol ranger will initiate stage III which will advise persons identified in the notification process to evacuate Bathhouse Row personnel. The National Park Service monitors the tunnel entrances during "normal business hours" between 8AM-5PM.

All concerned local agencies are aware of the flood preparedness plan and have received copies. In addition, copies of the plan are posted within the park at the following locations: Rangers Office, Maintenance Office, Administration Building, and Fordyce Bathhouse Visitor Center. The plan is reviewed annually and updated if necessary. Simulated flood exercises are done every three years to test the effectiveness of the plan.

Garland County Office of Emergency Services has developed a Local Emergency Operation Plan that describes the responsibilities and actions to be performed in the event of a natural, manmade, or technical hazard, but has no specific plan to deal with flooding of Central Avenue/Bathhouse Row. The plan notifies the Volunteer Fire Department in the event that search and rescue operations are needed.

iii. Warning and Evacuation:

a. NPS: Hot Springs National Park has exclusive law enforcement jurisdiction and primary responsibility for all flood plain activities within its boundaries, and according to the Flood Preparedness Plan can authorize the evacuation of personnel within the Bathhouse Row area.

b. City of Hot Springs: The Hot Springs City Police has the responsibility for dissemination of flood warnings to the local public. Public address systems are used by the city police and fire departments to issue the warning and evacuation notices. The Hot Springs Police Department is operational 24 hours a day and is also the designated location for the community 911 emergency telephone number. The Police Department building is located outside the flood plain and is supplied with emergency power. Currently, the City has seventy-six officers with 5-6 on patrol at all times and approximately thirty vehicles.

c. Garland County: Garland County has an office of Emergency Services. The office receives emergency management assistance funding from the Federal Emergency Management Agency, Region 6, Dallas, Texas, through the State Office in Little Rock, Arkansas and is matched by 25% funding from each the City and County. Ronald L. Jackson is currently the full time coordinator.

IV. Early Warning System Analysis:

A. Hydrologic Analysis:

A hydrologic analysis was performed to determine the flooding characteristics of the Central Avenue/Bathhouse Row area and show the effects of an EWS. The HEC-1 computer model from the Corps of Engineers 1990 Reconnaissance Study was used to determine basin runoff. A second model with higher loss rates was developed to give realistic flow values for the 0.5 to 10-year frequency floods and provide a better estimate of the minimum rainfall warning threshold for an EWS. Standard and front-end rainfall distribution storms were calculated for both models. Each model computed runoff for 0.5-1-, 2-, 5-, 10-, 25-, 50-, 100-, 500-year, and standard project flood (SPF) frequencies. The probable maximum flood was not analyzed since flooding exists at low frequencies and the storms generated by the Corps of Engineers give a sufficient range of floods for EWS calculations.

i. Basin Information: The drainage basin above Bathhouse Row/Central Avenue is highly vegetated and has an area of approximately 3.5 square miles. Elevations in the basin range from 630 to 1400 feet above sea level. Runoff from the western 2.16 square miles drains into the Whittington Creek tunnel while runoff from the eastern 0.89 square miles drains into Hot Springs Creek tunnel. An additional area 0.45 square miles which is below the tunnel entrances drains to Central Avenue. In the HEC-1 model, the basin above the Whittington Creek tunnel is divided into 3 subbasins and the basin above the Hot Springs Creek tunnel is a single basin. Listed below are the Synder lag and peaking coefficients used in the HEC-1 models.

Whittington Creek:

Basin	Lag	Peak Coef.
Subbasin 1	0.28	0.94
Subbasin 2	0.36	0.86
Subbasin 3	0.48	0.79

Hot Springs Creek:

Basin	Lag	Peak Coef.
Basin 1	0.55	0.77

The Corps of Engineers calculated a capacity of 615 ft^3/s for the Whittington Creek tunnel and a capacity of 950 ft^3/s for the Hot Springs Creek tunnel.

ii. Rainfall: Area rainfall values from the Corps of Engineers 1990 Reconnaissance study which were generated from U.S. Weather Bureau Technical Paper Nos. 40 and 49 were used in this study. Table 2 shows the rainfall depth duration values for various frequencies. Six hour storms with five-minute time intervals were used for all runoff calculations. Both standard and front-end rainfall distributions were analyzed. The standard rainfall distribution places the peak rainfall increment at the two-thirds point (hour 4) and arranges the remaining rainfall increments about that point. This rainfall distribution maximizes the peak flow. The front-end distribution places the peak rainfall increment in the first time period (5 minute) and second highest in the second time period and so on. This rainfall distribution produces the fastest peak flow and provides the potential warning times used in designing an EWS. The Corps of Engineers HEC-1 model used an initial loss

of 0.5 inches and a constant loss 0.05 inches. The revised model used an initial loss of 1.5 inches and a constant loss of 0.25 inches, which were calculated by matching the peak one-year runoff for Whittington Creek with its the tunnel capacity.

iii. Whittington Tunnel Entrance: The hydrologic analysis showed that the Whittington Creek tunnel has severe flooding problems. Table 3 gives a summary of the results. The tunnel's capacity is exceeded for a one-year frequency flood for all model runs, except the higher loss rate model using the front-end rainfall distribution. In addition, the 100-year standard distribution peak flows are 12 times the tunnel capacity. Figures 7 and 8 show the hydrographs calculated by the Corps of Engineers Model.

iv. Hot Springs Creek Tunnel Entrance: The hydrologic analysis showed that Hot Springs Creek tunnel also floods frequently. Table 3 give a summary of the results. Flooding at the Hot Springs Creek tunnel is slightly less severe than that of the Whittington Creek tunnel. Hot Springs Creek tunnel's capacity was exceeded for all five-year frequency floods, except for the higher loss rate model using the front-end distribution. The 100-year standard distribution peak flows are approximately 2.5 times the tunnel capacity. Figures 7 and 8 show the hydrographs calculated by the Corps of Engineers Model.

v. Summary: Both Hot Springs Creek and Whittington Creek have frequent flooding problems. Flooding will be noticed first at the Whittington Creek tunnel for most storms, since Whittington Creek tunnel drains a majority of the basin and has only two thirds the capacity of the Hot Springs tunnel. If the rainfall is evenly distributed over the drainage basin, the flooding at Hot Springs Creek tunnel lags the flooding at Whittington Creek tunnel by 10 minutes to 1.67 hours depending on the model and rainfall distribution used.

B. Analysis of Warning Times:

The effectiveness of an EWS for flooding in the Central Avenue/Bathhouse Row area of Hot Springs was shown by comparing warning times of the current observation method to warning times from a precipitation monitoring EWS. Table 4 summarizes the comparisons of warning times. It was assumed that the current observation method would issue a warning if the tunnels were flowing at 80 percent of their capacities. EWS warnings were based on six-hour rainfall warning thresholds of 0.86 and 1.60 inches for the Corps of Engineers model and the revised model, respectively. The analysis revealed a range of additional warning times from 10 minutes to 2 hours. In most cases, the flooding of Whittington Creek would control the issuing of a warning, for which an EWS would provide additional warning times from 10 to 35 minutes. Since the warning times shown are based on the tunnel capacities, there is additional time before flood water reaches the Central Avenue/Bathhouse Row area and becomes a dangerous condition.

C. Warning System Alternatives:

An EWS will give a more reliable warning with additional warning time and make it easier to disseminate the warning. In addition, an EWS provides a historical database which can be used to predict future flooding and improve calibration of hydraulic models. Three

alternative EWS configurations are given below with cost estimates presented on tables 4, 5, and 6. The alternatives present a range of EWSs that can be implemented. Alternative A is a full-option system, Alternative B is a reduced-option system, and Alternative C is the minimum recommended system. The alternatives shown are not packaged systems and options in Alternative A can be added to alternatives B and C to create other EWS configurations. An EWS without precipitation monitoring is not recommended since warning times would not be enhanced and many additional false alarms would be given. In addition, an EWS is not recommended if annual inspection, maintenance, and periodic testing can not be funded and performed. It is recommended that the EWS operator(s) join and attend the Southwestern Association of Alert Systems annual conference. These annual costs are shown for the alternatives below.

i. **Alternative A:** This alternative is a full-option EWS. Two rain gauges (one in each basin) would be located in the basins above Whittington Creek and Hot Springs tunnel entrances. Combination stream and rainfall gauges, with backup trigger sensors, would be located at the Whittington and Hot Springs Creek tunnel entrances. A repeater with an additional rain gauge would be located along the ridge of West Mountain. Fully equipped base stations would be located at both the National Park Headquarters and the Hot Springs police station. Installation, training, maintenance equipment, and integration into the NPS Flood Preparedness Plan are included (includes developement of inundation maps for Hot Springs Creek and Whittington Creek based on existing information). In addition, to assist in the dissemination of the flood warning along Central Avenue/Bathhouse Row, a voice siren and electronic fold-out signs are incorporated. The total cost, disadvantages, and advantages are as follows:

Total Cost:

$160,081 (See Table 5 for itemized costs)
$8,000 annual cost + staff salary

Disadvantages:

The initial cost

Advantages:

Additional warning devices for Central Avenue/Bathhouse Row
Redundant base station capabilities
Flood Preparedness Plan integrated with an automated EWS
Ability to share data with Arkansas Power and Light
Ability to issue a warning based on real-time precipitation
Reduced visitor risk

ii. **Alternative B:** Alternative B is a reduced-option EWS. It is similar to alternative A, except for some of the redundant base station features, the optional rain gauge at the repeater site, and the voice siren and electronic warning signs for the Central Avenue/Bathhouse row area have been removed. The total cost, disadvantages, and advantages are as follows:

Total Cost:

$121,113 (See Table 6 for itemized costs)
$7,000 annual cost + staff salary

Disadvantages:

Initial cost.
No Voice siren or electronic warning signs are provided to assist in evacuating the Central Avenue/Bathhouse Row area
No tape backup at base stations
Auto dialer and wide area network software for only one base station
No rainfall gauge at the repeater site.

Advantages:

Flood Preparedness Plan integrated with an automated EWS
Ability to share data with Arkansas Power and Light
Ability to issue a warning based on real-time precipitation
Reduced visitor risk

iii. **Alternative C:** Alternative C is the minimum recommended system. This system is similar to the other alternatives except all additional features have been removed. Compared to alternative B this alternative does not have stream flow pressure sensors at the stream gage sites, the base stations do not have wide area network and auto dialer software, and the field maintenance equipment has been minimized. The total cost, disadvantages, and advantages are as follows:

Total Cost:

$109,846 (See Table 7 for itemized costs)
$6,000 annual cost + staff salary

Disadvantages:

Initial cost
No Voice siren or electronic warning signs are provided to assist in evacuating the Central Avenue/Bathhouse Row area
No tape backup at base stations
No auto dialer and wide area network software at base stations
No rainfall gauge at the repeater site
Minimal field maintenance equipment.

Advantages:

Flood Preparedness Plan integrated with automated EWS
Ability to issue a warning based on real-time precipitation
Reduced visitor risk

V. Recommendations:

A. Early Warning System:

An EWS is highly recommended for the Central Avenue/Bathhouse Row area, since it is subject to flash flooding on a relatively frequent basis and visited year round by a large number of tourists. The small basin does not give adequate time for stream forecasting, but a precipitation-monitoring EWS will give from 10 to 120 minutes of additional warning time. The EWS would be integrated into the current NPS Flood Preparedness Plan. In addition, the Corps of Engineers is developing a long-term flood mitigation strategy which, when implemented, will incorporate the EWS to provide warnings for a wide range of flood magnitudes. The EWS presented in Alternative A is the recommended EWS hardware and software configuration. This alternative provides the most advantages for detecting hazardous flooding conditions and warning the population at risk in the Central Avenue/Bathhouse Row Area.

B. Flood Preparedness Plan For Central Avenue/Bathhouse Row:

The Flood Preparedness Plan For Central Avenue/Bathhouse Row should provide National Park Service staff notification procedures to be followed during an emergency situation at the tunnel to minimize property damage and loss of life.

i. Monitoring: The three staged approach used to detect and notify of flood danger is not a reliable process since the tunnel is only monitored during normal business hours. Twenty-four hour monitoring is recommended,

ii. Notification: For an emergency action plan to be effective, all persons having a role in correcting potentially dangerous conditions or evacuating persons at risk must be notified in an emergency. The Flood Preparedness Plan should link with Garland County's Office of Emergency Services Local Emergency Operation Plan during Stage II. Garland County Office of Emergency Services should be included on the notification list (unless the City Police Dept. or 911 has an understanding that this will automatically happen).

During Stage II, the patrol ranger has too many telephone calls to make in addition to ascertaining the condition of the flood waters. Once the Chief Ranger, Superintendent, and Assistant Superintendent have been notified during Stage 1, the above mentioned officials then notify the Facility Manager, Hot Springs City Police, and Garland County Office of Emergency Services. Then someone should initiate a fanout to notify the Bathhouse Row concessionaires. The patrol ranger then will be able to continue monitoring and communicate any changes. It is suggested that a fanout schematic be inserted in the plan.

Once Stage II has been initiated an Emergency Operation Center should be activated to coordinate all warning and evacuation response activities from the National Park Service with the Hot Springs City Police Department. The Garland County Office of Emergency Services, the county's recognized emergency operation center, may have already done this.

iii. Training/Exercising: Training of personnel involved in the plan should be conducted to insure that they are familiar with all elements of the plan. The Federal Emergency Management Agency has developed guidelines, "Exercise Design Course Guide to Emergency Management Exercises" (SM# 170.2, January 1989) to ensure consistency and uniformity with other Federal, state and local jurisdictions in meeting emergency exercise requirements. This exercise design training is available for all personnel involved in design and/or conduct of emergency exercises. The Federal Emergency Management Agency sponsors exercise design training offered by every State at no charge to participants other than travel, per diem, and salary.

Garland County Office of Emergency Services, participates in the State exercise program and would be able to assist the National Park Service in putting together an exercise design team to develop and conduct an exercise specifically designed to exercise the NPS Flood Preparedness Plan including an EWS if present for Central Avenue/Bathhouse Row.

iv. Coordination: Coordination with local officials responsible for warning and evacuation of the public is essential to ensure that there is agreement on roles and responsibilities. The present Plan will need revisions to accommodate any recommendations suggested in this report with or without installation of an EWS. Coordination with officials in Hot Springs is vital to the development and successful implementation of the Plan. A committee representing Hot Springs National Park (Roger Giddings, Dale Moss, or their representative), City of Hot Springs (Jim Atchley, or city delegate), and Garland County Office of Emergency Services (Ronald Jackson) should be formed.

A memorandum of understanding should be signed by Hot Springs National Park and the City of Hot Springs stating the intentions of the Plan and responsibilities of all parties involved.

v. Review: Plans should be updated after each change in involved personnel or their telephone numbers. The National Park Services and local governmental officials should conduct a comprehensive review of the adequacy of the emergency action plan annually.

C. Mitigation Strategies:

i. Block roads: In the event of any future flooding incidents, blocking off roads as soon as flooding occurs would prevent vehicles from entering the flooded area and assist in the evacuation of the population at risk. During the 1990 flooding, the Hot Springs Police Department had a difficult time with business owners trying to get back into town to check on their businesses.

ii. Outdoor warning systems: Given the potential number of people exposed to the threat of flooding in Hot Springs and the limited amount of warning time, it is apparent that a warning system with the capability to evaluate real-time data and rapidly disseminate warning instructions is needed in order to mitigate the impact from flooding.

Electronic loudspeaker (voice/sound) sound sources have the advantage that they can broadcast voices as well as siren-like sounds. They can advise people that a hazard exists and to take appropriate actions. Voice transmission sirens would allow for a more effective means of disseminating flood warnings, especially to tourists who would be unfamiliar with the situation, the terrain, and unsure about safety actions.

iii. Public awareness program: A public awareness program should be developed involving the National Park Service, merchants association, media, and public and private groups to heighten awareness of the hazard as a "designated flood hazard area". The information should include actions that can be taken to mitigate its effects, whether it be brochures and/ or "Climb To Safety" signs. Included in the brochure are buildings that have been identified as "safe havens".

According to the definitions contained in the NPS Floodplain Management Guideline, July 1, 1993, the Central Avenue/Bathhouse Row area would be considered a "high hazard area" which is subject to "flash flooding".

The City of Hot Springs depends upon tourism for its economic base, while the Hot Springs National Park attracts visitors who indulge in various kinds of tubs or pools of thermal water. One concern that may be raised by community members is the fear that preparedness planning might discourage tourism. Fears along this line are unfounded. As an example, Estes Park, Colorado, suffered the equivalent of a 500-year flood in 1982 due to a dam break. Within a week the town's tourism exceeded preflood levels. A well-prepared community is more attractive than one that is ill-prepared.

iv. Warning, Evacuation, and Rescue Plan: Whether or not an Early Warning System is installed to prevent loss of life and reduce property damage from flooding, the Hot Springs National Park and the City of Hot Springs must develop and be able to implement a warning, evacuation and rescue plan specific to respond to flooding on Central Avenue/Bathhouse Row. The plan should be a "hazard specific annex" part of Garland County's Office of Emergency Services, Local Emergency Operation Plan, or a stand alone plan.

The Hot Springs National Park and the City of Hot Springs should have established procedures for issuing a warning to the public. These procedures will provide warnings to businesses directly threatened by the flood waters and to the general public. The warning function describes the jurisdiction's warning system and the responsibilities and procedures for using them. Warnings can be disseminated by telephone, radio, television, personal communication, sirens, or public address systems.

The evacuation plan should identify the best evacuation routes available in addition to describing policies, roles, responsibilities, and procedures, for evacuating people when necessary.

The Federal Emergency Management Agency is the Federal agency responsible for enforcing the legislation for disaster emergency planning and response. With a year round population the size of the City of Hot Springs and the tourist population for Hot Springs

National Park, a full time position for the city of Hot Springs to coordinate emergency management planning is not out of the question. Matching funds from the Federal Emergency Management Agency may be available if the situation warrants it.

v. Establish a long-term implementation task force: The City of Hot Springs and the National Park Service should formally establish an intergovernmental, interagency, and interdisciplinary task force to assist in the continued development and implementation of the warning and evacuation planning of Central Avenue/Bathhouse Row.

vi. National Flood Insurance Program: Garland County and the City of Hot Springs have been participating in the National Flood Insurance Program since December 18, 1979. This program provides for a subsidized rate for structures located in the flood hazard areas, and requires that flood plain use controls be adopted. Strategies used for achieving flood loss reduction include: local zoning, subdivision, building code, housing code, sanitary and well code, and other regulations.

VI. Conclusions:

Hot Springs Creek at Hot Springs National Park, Arkansas is subject to relatively frequent flash flooding. The current flood warning operations can be significantly enhanced by integrating an EWS, revising the NPS Flood Preparedness Plan. and using mitigation strategies.

Table 1

High Water Marks for Flood of May 19-20, 1990

Hot Springs, Arkansas

HWM No.	HWM Elevation	Description of High Water Mark (HWM)
Hot Springs Creek along Central Avenue		
HSC24	629.9	Hear Rock Cafe-Bakery 101 Central Avenue. HWM is 1.83 fee on downstream side of building
HSC32	627.0	Downtowner Hotel entrance on Central Avenue. HWM's are 0.92 feet above outside window sill of lobby window and 3.54 feet above lobby floor inside
HSC33	624.7	DeSoto Hotel. HWM is 3.53 feet above outside sidewalk
HSC44	623.2	New Orleans Cafe, 210 Central Avenue. HWM is 2.67 feet over door sill.
HSC35	622.3	National Park Aquarium 209 Central Avenue. HWM is 2.31 feet above floor.
HSC37	620.9	Arlington Hotel. HWM is 7 feet of water in basement.
HSC38	619.5	The Classic Lady Aristocrat Motel, 238 Central Avenue. HWM is 3.8 feet above door sill.
HSC57	617.2	Wax Museum, 250 Central Avenue. HWM is 2.5 feet above floor on outside door.
HSC67	612.5	Toy Chest, 348 Central Avenue. HWM is 2.83 feet above sidewalk.
HSC70	611.4	Palm Reader, 364 Central Avenue. HWM is 3.25 feet above sidewalk.
HSC80	603.0	Hot Springs Info Office, 600 Central Avenue. HWM is 3.17 feet above sidewalk.
HSC90	598.7	Sensational Sal's Yogurt at Spencer's Corner. HWM is 3.46 feet above floor on back wall of store.
HSC85	598.4	Lockwood's Mens Store, 726 Central Avenue. HWM is 4.08 feet above sidewalk.
HSC94	596.3	Our House Lounge and Restaurant at corner of Convention Boulevard and Malvern Avenue. HWM is 2.42 feet above outside sidewalk at entrance.
Hot Springs Creek along Park Avenue		
HSC96	630.8	Majestic Sundry Store. HWM is 1.17 feet above door sill of Majestic Sundry Store on outside of glass door.
HSC101	641.2	HWM is on the second power pole upstream of the Park Avenue and Ramble Street intersection. A nail 1.0 feet above ground level is the height of the HWM
HSC105	646.9	HWM is 1.12 feet above base of Air Conditioner Compressor on the back of northwest corner of Zac's Pizza at 501 Park Avenue.
HSC106	659.2	HWM is 0.5 foot above sidewalk against first step of Caruth Funeral Home at the corner of Holly Street and Park Avenue.
Whittington Creek		
WC28	634.4	The HWM is 4.92 feet above sidewalk at the entrance to First Presbyterian Church adjacent to parking lot.
WC32	632.4	The HWM is 1.96 feet high on emergency parking lot door to Doctor's Clinic on Water Street.
WC35	631.2	The HWM is at first parking meter on Whittington Avenue in front of St. Mary's Catholic Church. The HWM is 4.0 feet above ground level at the parking meter.

Table 2

Area Rainfall Data for Hot Springs Creek*

Hot Springs, Arkansas

(Drainage Area = 7.8 Square Miles)

Duration in Hours	Frequency in Years									
	0.5	1	2	5	10	25	50	100	500	SPF
0.50	1.00	1.29	1.50	1.88	2.12	2.44	2.72	3.03	3.74	3.08
1.00	1.25	1.59	1.82	2.32	2.70	3.09	3.49	3.81	4.54	4.03
1.50	1.38	1.78	2.10	2.66	3.08	3.52	3.95	4.36	5.31	4.88
2.00	1.48	1.92	2.30	2.90	3.35	3.83	4.28	4.75	5.85	5.62
2.50	1.56	2.04	2.42	3.09	3.55	4.06	4.53	5.04	6.22	6.36
3.00	1.63	2.14	2.52	3.24	3.73	4.27	4.76	5.29	6.53	7.10
3.50	1.70	2.23	2.62	3.38	3.89	4.46	4.97	5.53	6.83	7.74
4.00	1.75	2.31	2.71	3.50	4.04	4.65	5.17	5.75	7.10	8.38
4.50	1.80	2.38	2.79	3.61	4.17	4.81	5.34	5.94	7.34	9.02
5.00	1.85	2.45	2.87	3.71	4.29	4.96	5.50	6.11	7.55	9.55
5.50	1.90	2.51	2.94	3.80	4.40	5.09	5.64	6.27	7.74	10.08
6.00	1.95	2.57	3.01	3.89	4.50	5.21	5.77	6.42	7.92	10.61
12.00	2.38	3.06	3.64	4.69	5.38	6.29	6.91	7.68	9.43	14.27
24.00	2.78	3.60	4.21	5.41	6.44	7.32	8.05	8.93	10.96	18.30

* Rainfall generated from U.S. Weather Bureau Technical Papers Nos. 40 and 49 for 1990 Corps of Engineers Reconnaissance study.

Table 3

Peak Flow, Time of Peak Flow, and Time of *Full Capacity

at Whittington Creek and Hot Springs Creek Tunnel Entrances

Location/Storm	Flow / Time (Ft3/Sec) / (Hr)	Frequency in Years 1	5	25	50	100	500
Whittington Creek:							
1. Standard (COE)	Peak Flow	2648	4084	5993	6926	7583	9023
	Time of Peak Flow	4.50	4.50	4.50	4.50	4.50	4.50
	Time of Full Capacity	4.08	3.50	3.17	3.00	2.83	2.33
2. Standard (revised)	Peak Flow	1185	3312	5466	6471	7183	8668
	Time of Peak Flow	4.50	4.50	4.50	4.50	4.50	4.50
	Time of Full Capacity	4.25	4.17	4.08	4.00	3.75	3.33
3. Front-End (COE)	Peak Flow	1419	2547	3791	4748	5255	6383
	Time of Peak Flow	0.58	0.58	0.58	0.58	0.58	0.58
	Time of Full Capacity	0.33	0.25	0.17	0.17	0.17	0.17
4. Front-End (revised)	Peak Flow	175	623	1776	2478	2853	3668
	Time of Peak Flow	1.83	0.75	0.58	0.58	0.58	0.58
	Time of Full Capacity	No Flooding	0.67	0.33	0.25	0.25	0.25
Hot Springs Creek:							
1. Standard (COE)	Peak Flow	1161	1676	2268	2569	2777	3268
	Time of Peak Flow	4.50	4.50	4.50	4.50	4.50	4.50
	Time of Full Capacity	4.33	4.25	4.17	4.17	4.08	4.00
2. Standard (revised)	Peak Flow	532	1417	2126	2436	2662	3152
	Time of Peak Flow	4.50	4.50	4.50	4.50	4.50	4.50
	Time of Full Capacity	No Flooding	4.33	4.17	4.17	4.17	4.08
3. Front-End (COE)	Peak Flow	669	1105	1620	1915	2073	2438
	Time of Peak Flow	0.58	0.67	0.58	0.58	0.58	0.67
	Time of Full Capacity	No Flooding	0.42	0.33	0.33	0.33	0.33
4. Front-End (revised)	Peak Flow	55	287	794	1081	1246	1611
	Time of Peak Flow	1.75	1.58	0.75	0.67	0.67	0.67
	Time of Full Capacity	No Flooding	No Flooding	No Flooding	0.50	0.50	0.42

Full Capacity* of Whittington Creek Tunnel = 615 Ft3/Sec
Full Capacity* of Hot Springs Creek Tunnel = 950 Ft3/Sec
* Tunnel Capacities based on Corps of Engineers Rating Curve

Table 4
Comparison of Warning Times
Existing Conditions vs Early Warning System

Location/Storm	Warning System	Frequency in Years					
		1	5	25	50	100	500
Whittington Creek:							
1. Standard (COE)	Existing Conditions	5	15	15	15	15	15
	EWS	15	30	35	35	30	25
	Additional Warning Time from EWS	10	15	20	20	15	10
2. Standard (revised)	Existing Conditions	5	5	5	5	5	5
	EWS	15	15	30	40	35	30
	Additional Warning Time from EWS	10	10	25	35	30	25
3. Front-End (COE)	Existing Conditions	5	5	5	5	5	5
	EWS	25	20	15	15	15	15
	Additional Warning Time from EWS	20	15	10	10	10	10
4. Front-End (revised)	Existing Conditions	No Warning	5	5	5	5	5
	EWS	False Alarm	35	15	15	15	15
	Additional Warning Time from EWS	0	30	10	10	10	10
Hot Springs Creek:							
1. Standard (COE)	Existing Conditions	5	5	5	5	5	15
	EWS	25	70	95	105	115	130
	Additional Warning Time from EWS	20	65	90	100	110	115
2. Standard (revised)	Existing Conditions	False Alarm	5	5	5	5	5
	EWS	False Alarm	85	100	110	120	135
	Additional Warning Time from EWS	0	80	95	105	115	130
3. Front-End (COE)	Existing Conditions	No Warning	5	5	5	5	5
	EWS	False Alarm	30	25	25	25	20
	Additional Warning Time from EWS	0	25	20	20	20	15
4. Front-End (revised)	Existing Conditions	No Warning	No Warning	False Alarm	5	5	5
	EWS	False Alarm	False Alarm	False Alarm	15	15	15
	Additional Warning Time from EWS	0	0	0	10	10	10

Table 5
EWS Alternative A - Cost Sheet

Field Hardware: - $30,865

> **Two Complete Rainfall Stations - $8,430 ($4,215 each)**
  Includes: Standpipe assembly, tipping bucket rain gage, VHF transmitter, VHF omni antenna (cable and connectors included) with lighting protection, and solar panel with mounting bracket

> **Two Stream Level/Rainfall Stations with Trigger Level Sensors- $15,910 ($7,955 each)**
  Includes: Standpipe assembly, pressure sensor, high and low trigger sensors, tipping bucket rain gage, VHF transmitter, VHF omni antenna with lighting protection, solar panel with mounting bracket, and all necessary cabling for sensor and antenna connections.

> **VHF Radio Repeater - $6,525**
  Includes: Standpipe assembly, dual frequency repeater, solar panel with mounting bracket, high gain omni antenna with mast mounting, lightning protection, cables, and connections. - $5,830
  Options: Rain gage - $695

Two Base Stations - $32,325

> **Hardware for Two Base Stations - $21,350 ($10,675 each)**
  Includes: 486 Personal Computer, VHF receiver and decoder, 6 dB/360 degree VHF omni antenna with lightning protection, 9600 baud modem, 1000VA/60 Hz battery backup system, and all necessary cabling - $15,630 ($7,815 each)
  Options: 150/250 megabyte tapeback module with adapter card - $3920 ($1960 each)
  8-port Serial Multiport - $1800 ($900 each)

> **Software for Two Base Stations - $10,975**
  Includes: Novastar software, QNX operating system software - $9,225 ($4,613 each)
  Options: Autodialer software - $550 ($275 each)
  Wide area network dial-out software - $1,200 ($600 each)

Accessories - $36,738

> **Field Maintaince Equipment - $3,785**

Options:	notebook portable computer (with Fax/Modem)	$2,750
	Procomm communications software	$175
	Cable for gage transmitter	$55
	Battery charger	$110
	Battery discharger	$695

> **Two Automatic Warning Signs - $17,000 (includes installation)** - Electronic foldout warning signs with lights, radio controlled by EWS

> **Voice Warning Speaker - $11,135 (includes installation)**

> **Spare Parts - $4,818**
  Includes: Rain Gauge Top Section, Transmitter, Pressure Transducer with cable, Two Batteries, and Solar Panel with Mounting Bracket.

Installation and Training - $18,100

Includes: Hardware Installation for Two Base Stations, Software Installation and Training for Two Base Stations, Hardware Installations and Training for Field Hardware.

Flood Preparedness Plan Revision - $23,700

Includes: Local Scoping Meeting, Revision of NPS Preparedness Plan (Revision, Review, and Final Draft), and Plan Exercise. Inundation Maps for Hot Springs Creek and Whittington Creek based on existing information.

Totals

Field Hardware	$30,865
Base Stations	$32,325
Accessories	$36,738
Installation and Training	$18,100
Flood Preparedness Plan Revision	$23,700
Subtotal	$141,728
Less 10% GSA Discount on Equipment	$9,993
Plus 20% Contingencies	$28,346
Total Cost of Alternative A	**$160,081**

Table 6
EWS Alternative B - Cost Sheet

Field Hardware: - $30,170

> **Two Complete Rainfall Stations - $8,430 ($4,215 each)**
Includes: Standpipe assembly, tipping bucket rain gage, VHF transmitter, VHF omni antenna (cable and connectors included) with lighting protection, and solar panel with mounting bracket

> **Two Stream Level/Rainfall Stations with Trigger Level Sensors- $15,910 ($7,955 each)**
Includes: Standpipe assembly, pressure sensor, high and low trigger sensors, tipping bucket rain gage, VHF transmitter, VHF omni antenna with lighting protection, solar panel with mounting bracket, and all necessary cabling for sensor and antenna connections.

> **Repeater - $5,830**
Includes: Standpipe assembly, dual frequency repeater, solar panel with mounting bracket, high gain omni antenna with mast mounting, lightning protection, cables, and connections. - $5,830

Two Base Stations - $25,730

> **Hardware for Two Base Stations - $15,630 ($7,815 each)**
Includes: 486 Personal Computer, VHF receiver and decoder, 6 dB/360 degree VHF omni antenna with lightning protection, 9600 baud modem, 1000VA/60 Hz battery backup system, and all necessary cabling

> **Software for Two Base Stations - $10,100**
Includes: Novastar software, QNX operating system software - $9,225 ($4,613 each)
Options: Autodialer software - $275
Wide area network dial-out software - $600

Accessories - $8,603

> **Field Maintaince Equipment - $3,785**

Options:	Notebook portable computer (with fax/modem)	$2,750
	Procomm communications software	$175
	Cable for gage transmitter	$55
	Battery charger	$110
	Battery discharger	$695

> **Spare Parts - $4,818**
Includes: Rain gauge top section, transmitter, pressure transducer with cable, two batteries, and solar panel with mounting bracket.

Installation and Training - $18,100

Includes: Hardware installation for two base stations, software installation and training for two base stations, hardware installations and training for field hardware.

Flood Preparedness Plan Revision - $23,700

Includes: Local Scoping Meeting, Revision of NPS Preparedness Plan (Revision, Review, and Final Draft), and Plan Exercise. Inundation Maps for Hot Springs Creek and Whittington Creek based on existing information.

Totals

Field Hardware	$30,170
Base Stations	$25,730
Accessories	$8,603
Installation and Training	$18,100
Flood Preparedness Plan Revision	$23,700
Subtotal	$106,303
Less 10% GSA Discount on Equipment	$6,450
Plus 20% Contingencies	$21,261
Total Price for Alternative B	**$121,113**

Table 7
EWS Alternative C - Cost Sheet

Field Hardware: - $25,240

> **Two Complete Rainfall Stations - $8,430 ($4,215 each)**
Includes: Standpipe assembly, tipping bucket rain gage, VHF transmitter, VHF omni antenna (cable and connectors included) with lighting protection, and solar panel with mounting bracket

> **Two Rainfall Stations with Trigger Level Sensors- $10,980 ($5,490 each)**
Includes: Standpipe assembly, high and low trigger sensors, tipping bucket rain gage, VHF transmitter, VHF omni antenna with lighting protection, solar panel with mounting bracket, and all necessary cabling for sensor and antenna connections.

> **Repeater - $5,830**
Includes: Standpipe assembly, dual frequency repeater, solar panel with mounting bracket, high gain omni antenna with mast mounting, lightning protection, cables, and connections. - $5,830

Two Base Stations - $24,855

> **Hardware for Two Base Stations - $15,630 ($7,815 each)**
Includes: 486 Personal Computer, VHF receiver and decoder, 6 dB/360 degree VHF omni antenna with lightning protection, 9600 baud modem, 1000VA/60 Hz battery backup system, and all necessary cabling

> **Software for Two Base Stations - $9,225 ($4,613 each)**
Includes: Novastar software and QNX operating system software

Accessories - $4,165

> **Field Maintaince Equipment - $165**

Cable for gage transmitter	$55
Battery charger	$110

> **Spare Parts - $4,000**
Includes: Rain gauge top section, transmitter, two batteries, and solar panel with mounting bracket.

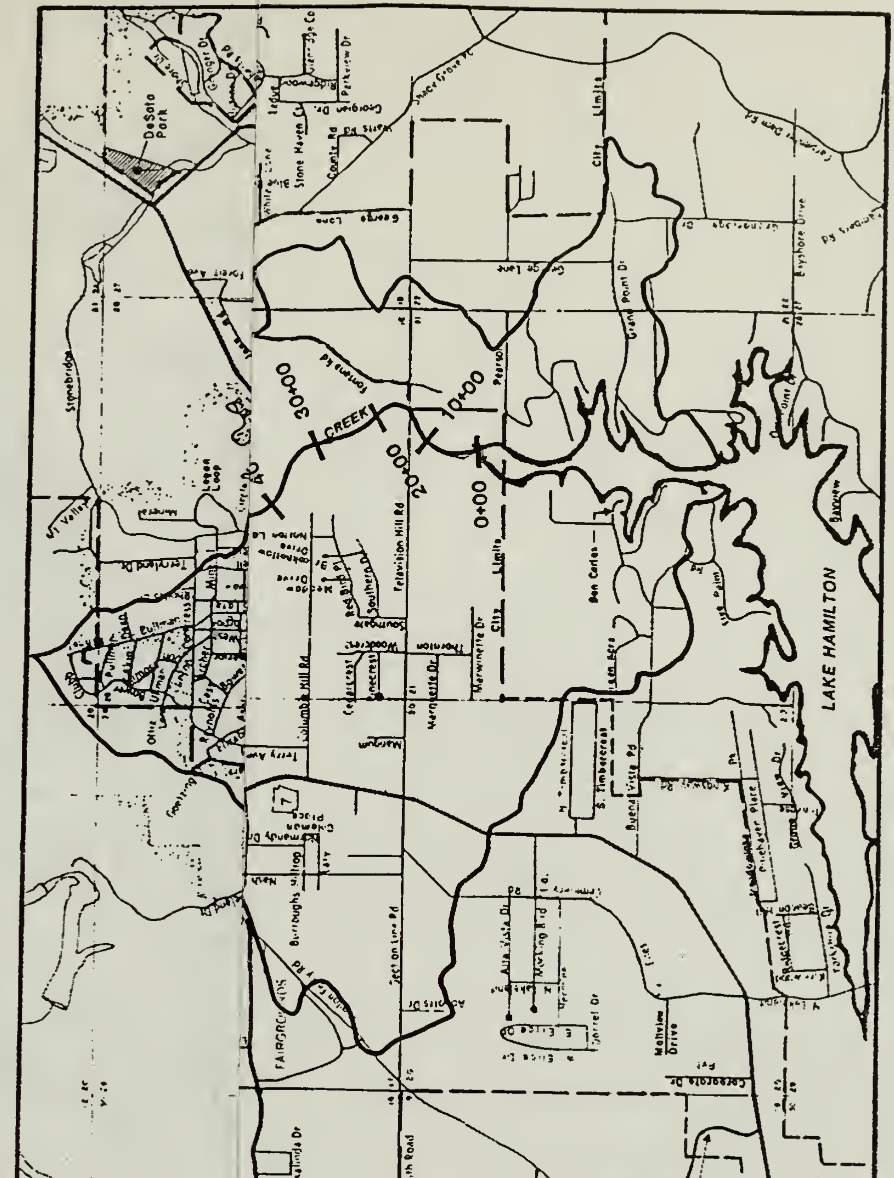
Installation and Training - $18,100

Includes: Hardware Installation for Two Base Stations, Software Installation and Training for Two Base Stations, Hardware Installations and Training for Field Hardware.

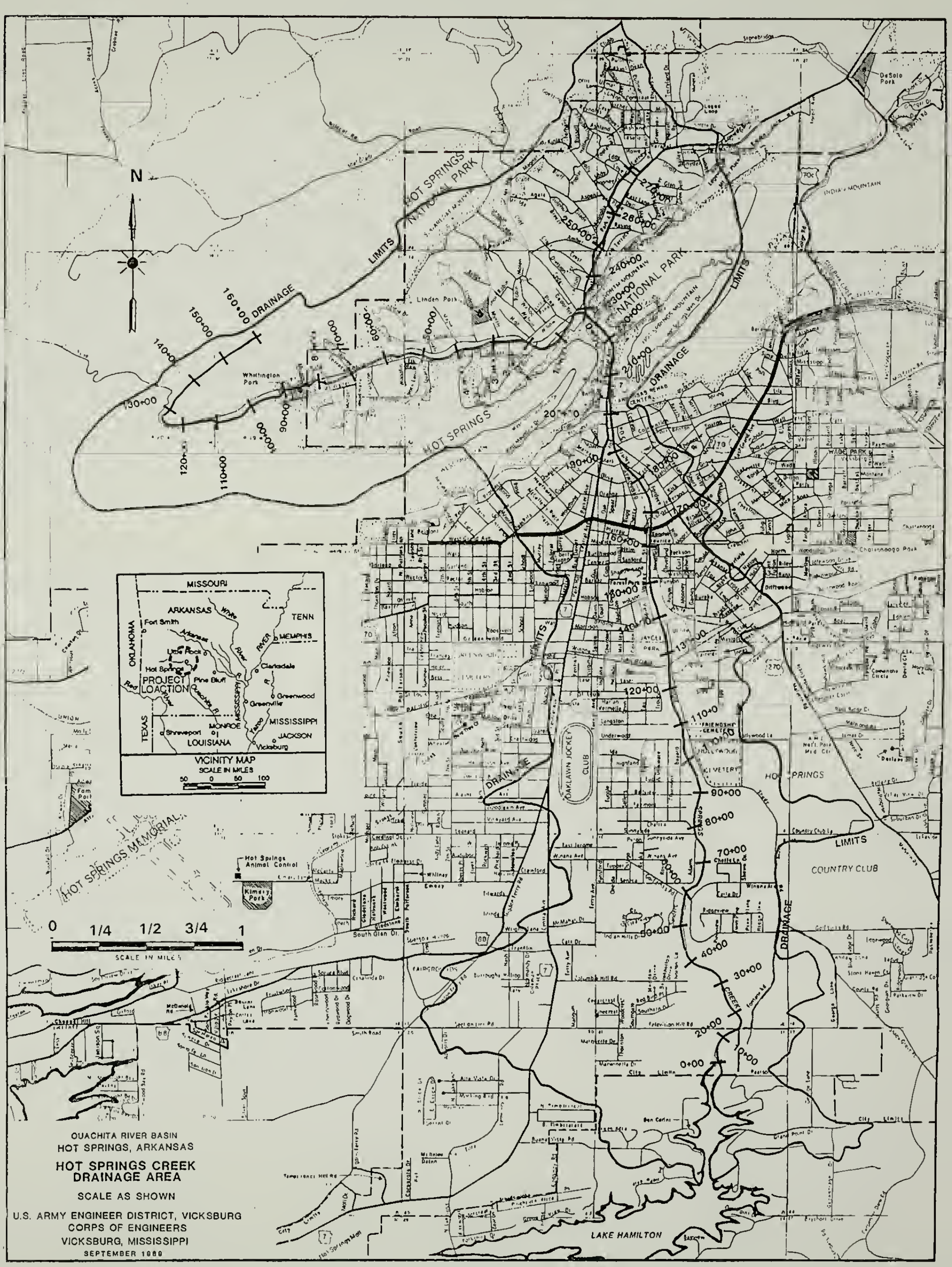
Flood Preparedness Plan Revision - $23,700

Includes: Local Scoping Meeting, Revision of NPS Preparedness Plan (Revision, Review, and Final Draft), and Plan Exercise. Inundation Maps for Hot Springs Creek and Whittington Creek based on existing information.

	Totals
Field Hardware	$25,240
Base Stations	$24,855
Accessories	$4,165
Installation and Training	$18,100
Flood Preparedness Plan Revision	$23,700
Subtotal	$96,060
Less 10% GSA Discount on Equipment	$5,426
Plus 20% Contingencies	$19,212
Total Price for Alternative C	**$109,846**


OUACHITA RIVER BASIN
HOT SPRINGS, ARKANSAS
HOT SPRINGS CREEK
DRAINAGE AREA
SCALE AS SHOWN
U.S. ARMY ENGINEER DISTRICT, VICKSBURG
CORPS OF ENGINEERS
VICKSBURG, MISSISSIPPI
SEPTEMBER 1989
SCALE IN MILES
LAKE HAMILTON
DeSoto Park
CREEK
0+00
10+00
20+00
30+00
FAIRGROUNDS

Figure



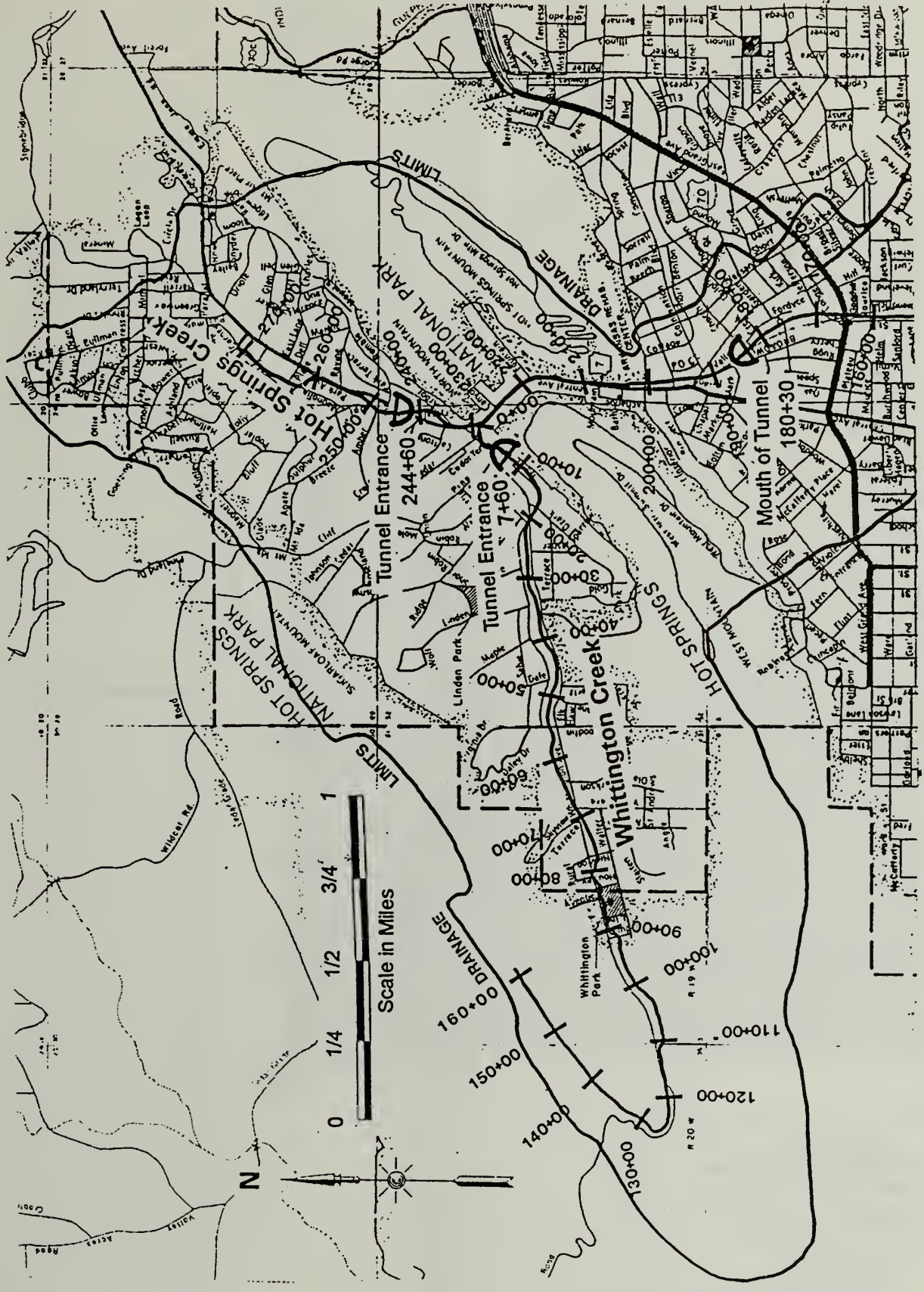
OUACHITA RIVER BASIN
HOT SPRINGS, ARKANSAS

HOT SPRINGS CREEK DRAINAGE AREA

SCALE AS SHOWN

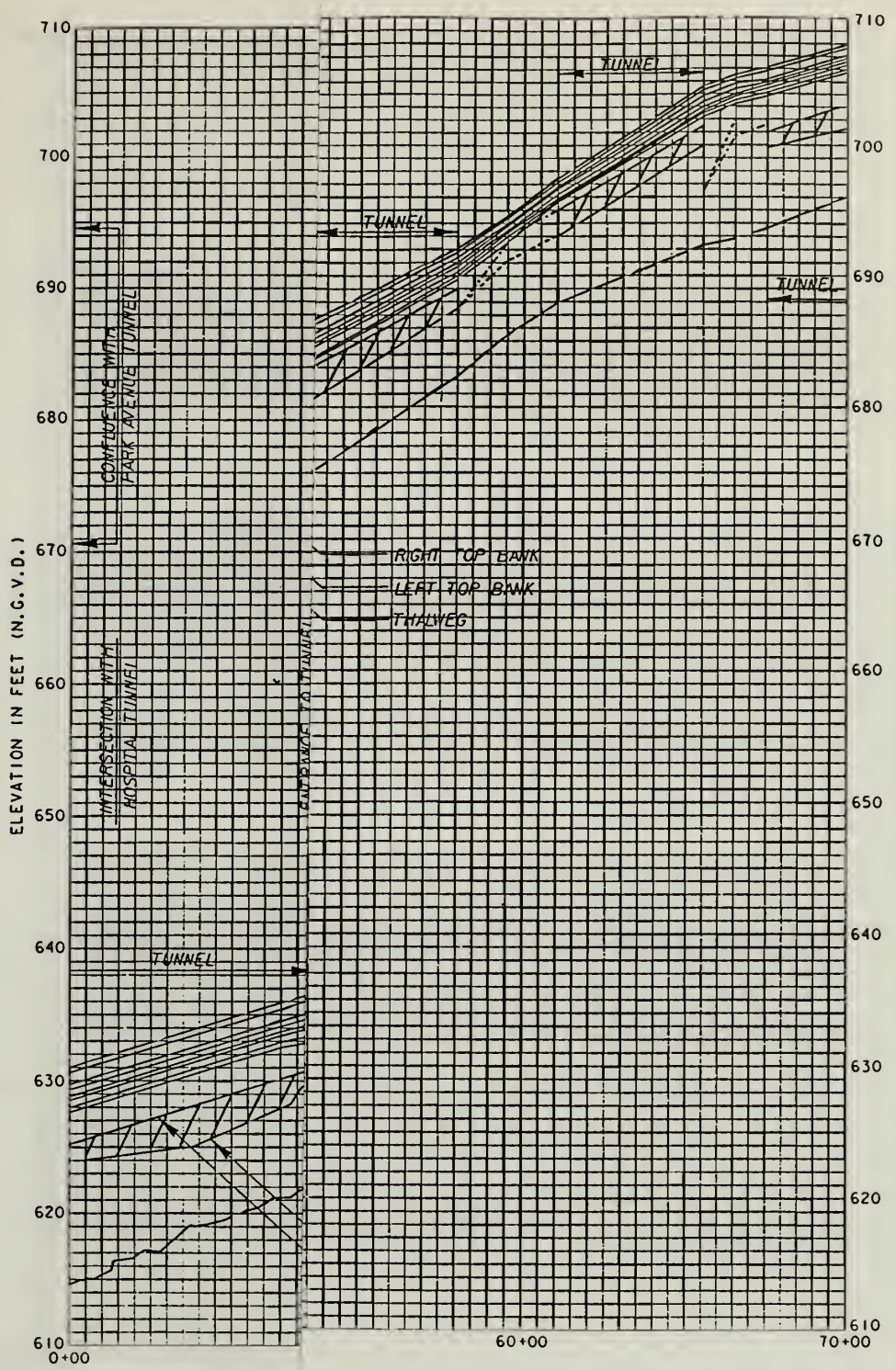
U.S. ARMY ENGINEER DISTRICT, VICKSBURG
CORPS OF ENGINEERS
VICKSBURG, MISSISSIPPI
SEPTEMBER 1980

Figure 1 - Hot Springs Creek Location and Drainage Area Map, Hot Springs, Arkansas



F-2

Figure 2 - - Upper Hot Springs Creek Drainage Area, Hot Springs, Arkansas

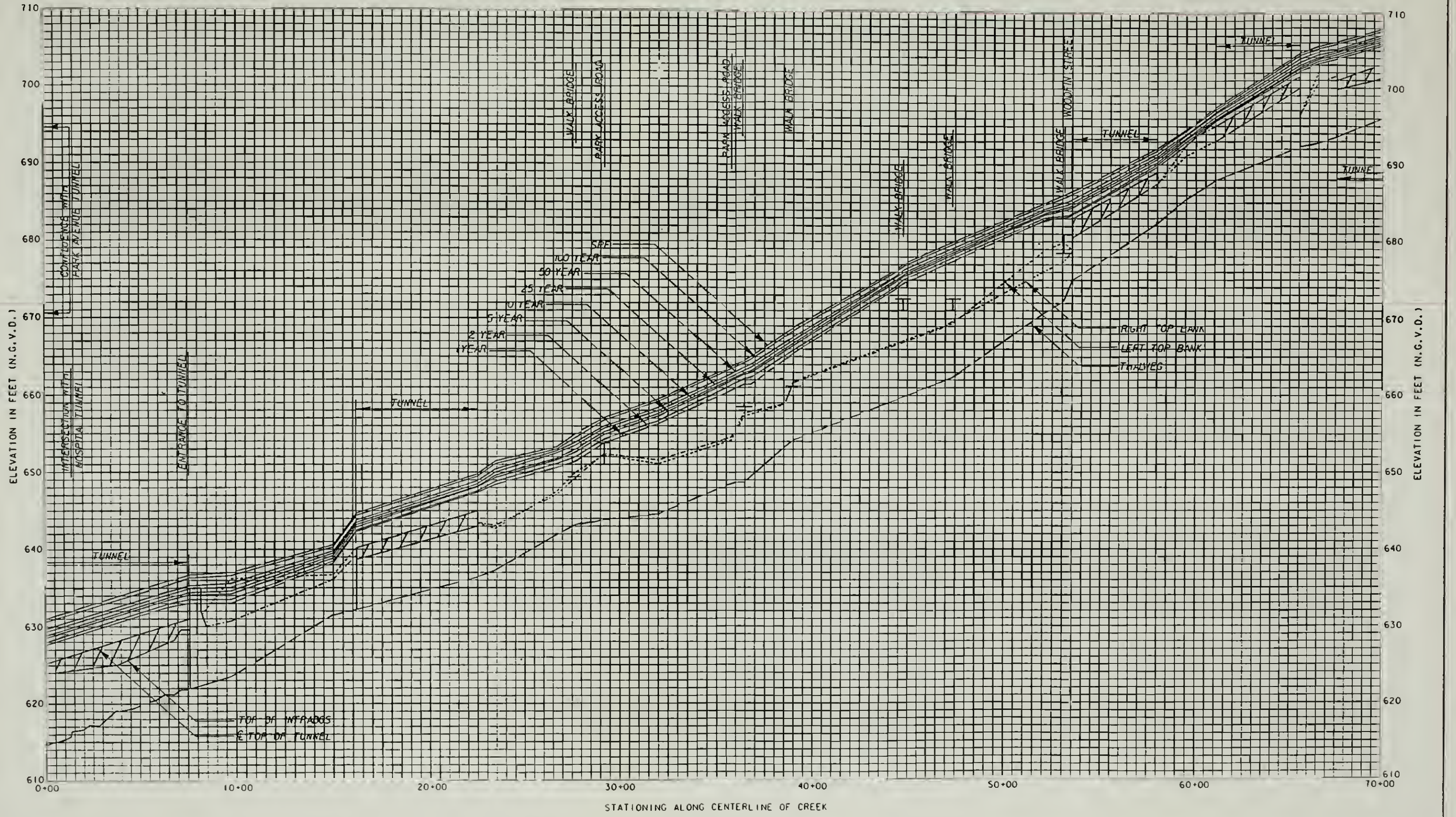


OUACHITA RIVER BASIN
HOT SPRINGS, ARKANSAS
FLOOD CONTROL RECONNAISSANCE STUDY
WHITTINGTON AVENUE TRIBUTARY

EXISTING CONDITIONS
STA. 0+00 TO STA. 70+00

SCALES AS SHOWN
U. S. ARMY ENGINEER DISTRICT, VICKSBURG
CORPS OF ENGINEERS
VICKSBURG, MISSISSIPPI
DATE: JAN 90

Figure 3 - Existing
(Corps

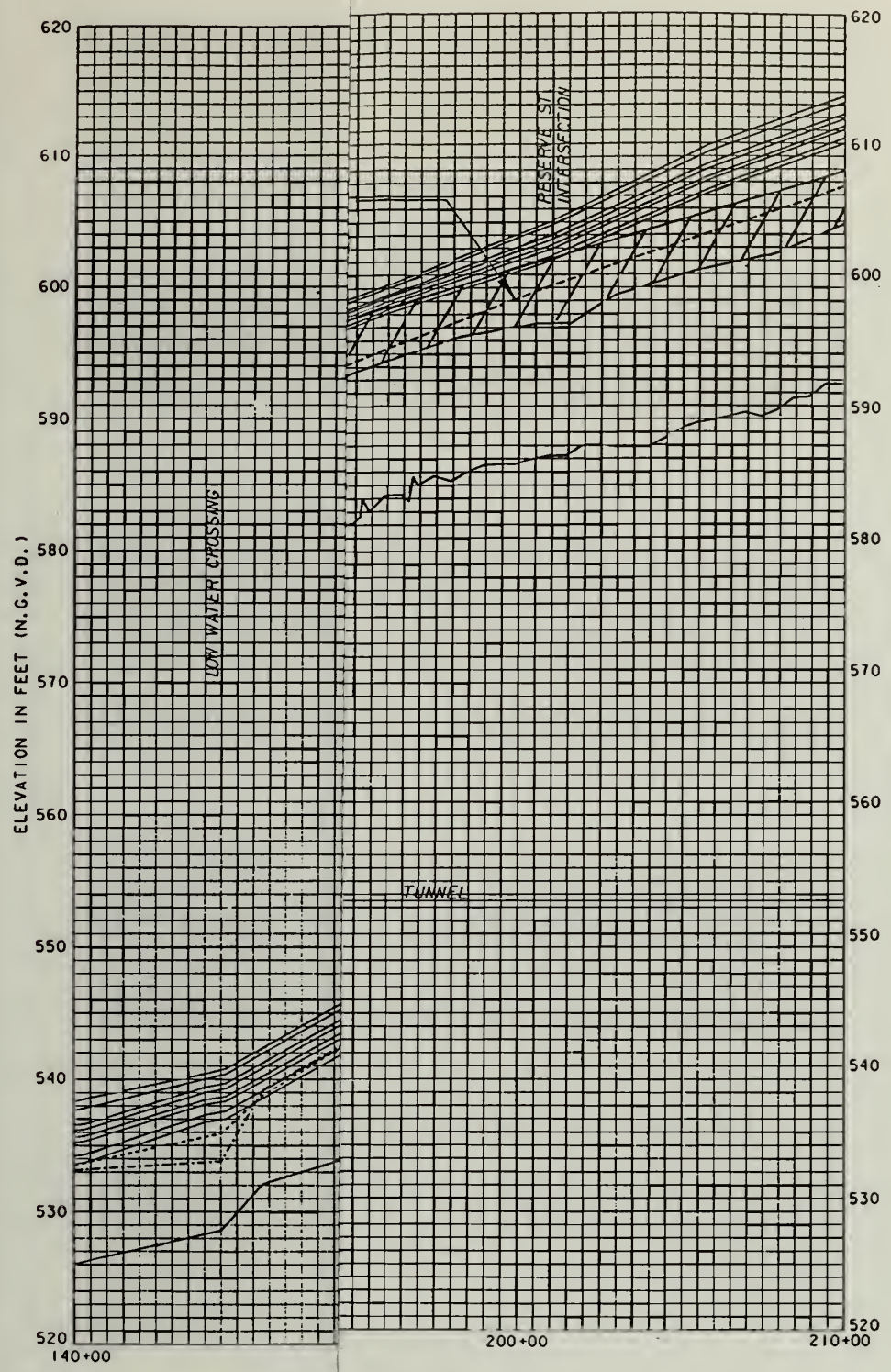


OUACHITA RIVER BASIN
HOT SPRINGS, ARKANSAS
FLOOD CONTROL RECONNAISSANCE STUDY
WHITTINGTON AVENUE TRIBUTARY

EXISTING CONDITIONS
STA. 0+00 TO STA. 70+00

SCALES AS SHOWN
U. S. ARMY ENGINEER DISTRICT, VICKSBURG
CORPS OF ENGINEERS
VICKSBURG, MISSISSIPPI
DATE: JAN 90

Figure 3 - Existing Conditions Profiles for Whittington Creek, Station 0+00 to 70+00
(Corps of Engineers 1990 Reconnaissance Study)

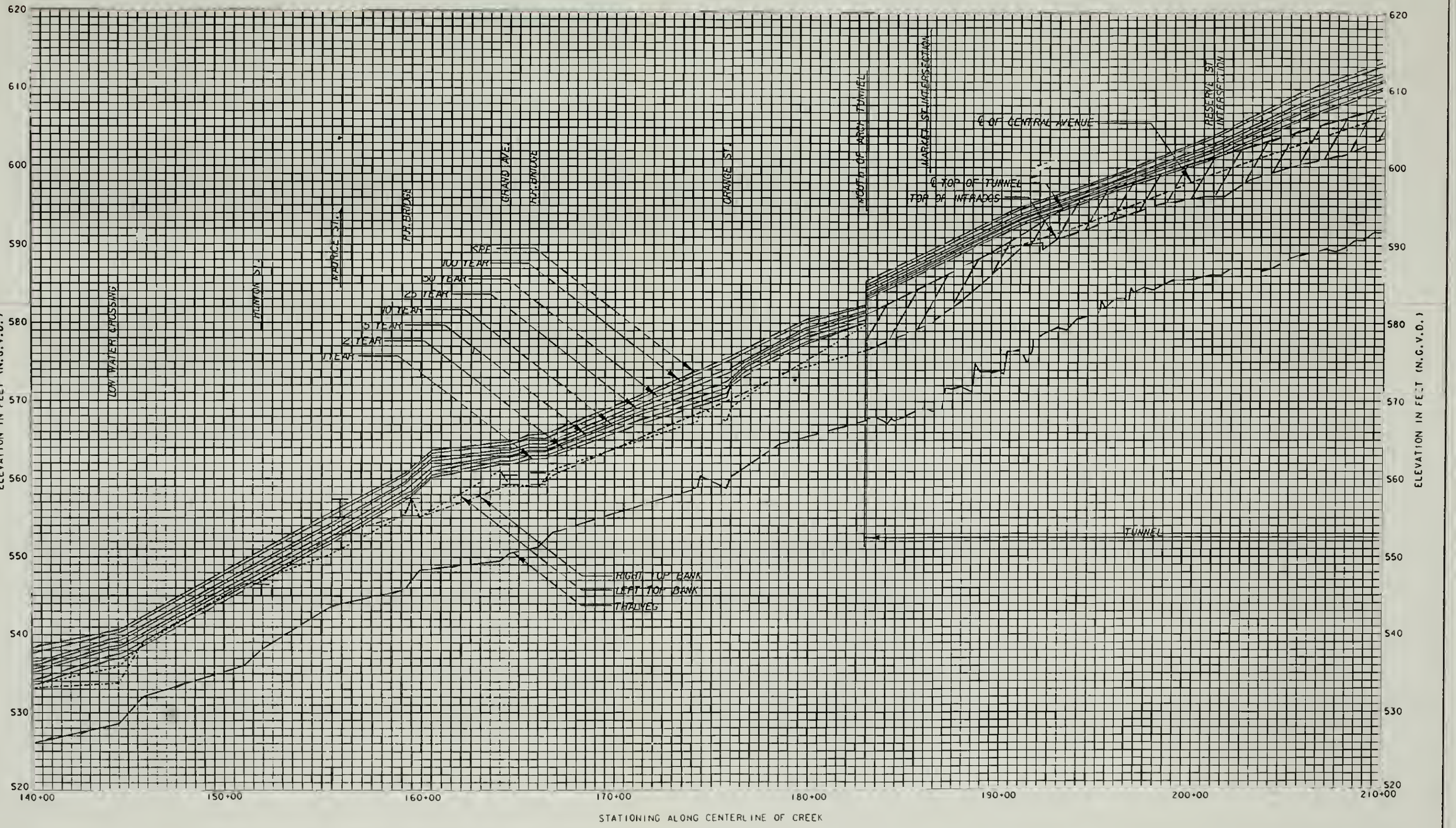


OUACHITA RIVER BASIN
HOT SPRINGS, ARKANSAS
FLOOD CONTROL RECONNAISSANCE STUDY
HOT SPRINGS CREEK

EXISTING CONDITIONS
STA. 140+00 TO STA. 210+00

SCALES AS SHOWN
U. S. ARMY ENGINEER DISTRICT, VICKSBURG
CORPS OF ENGINEERS
VICKSBURG, MISSISSIPPI
DATE: JAN 90

Figure 4 - Existing
(Corps of



OUACHITA RIVER BASIN
HOT SPRINGS, ARKANSAS
FLOOD CONTROL RECONNAISSANCE STUDY
HOT SPRINGS CREEK
EXISTING CONDITIONS
STA. 140+00 TO STA. 210+00
SCALES AS SHOWN
U. S. ARMY ENGINEER DISTRICT, VICKSBURG
CORPS OF ENGINEERS
VICKSBURG, MISSISSIPPI
DATE: JAN 90

Figure 4 - Existing Conditions Profiles for Hot Springs Creek, Station 140+00 to 210+00
(Corps of Engineers 1990 Reconnaissance Study)

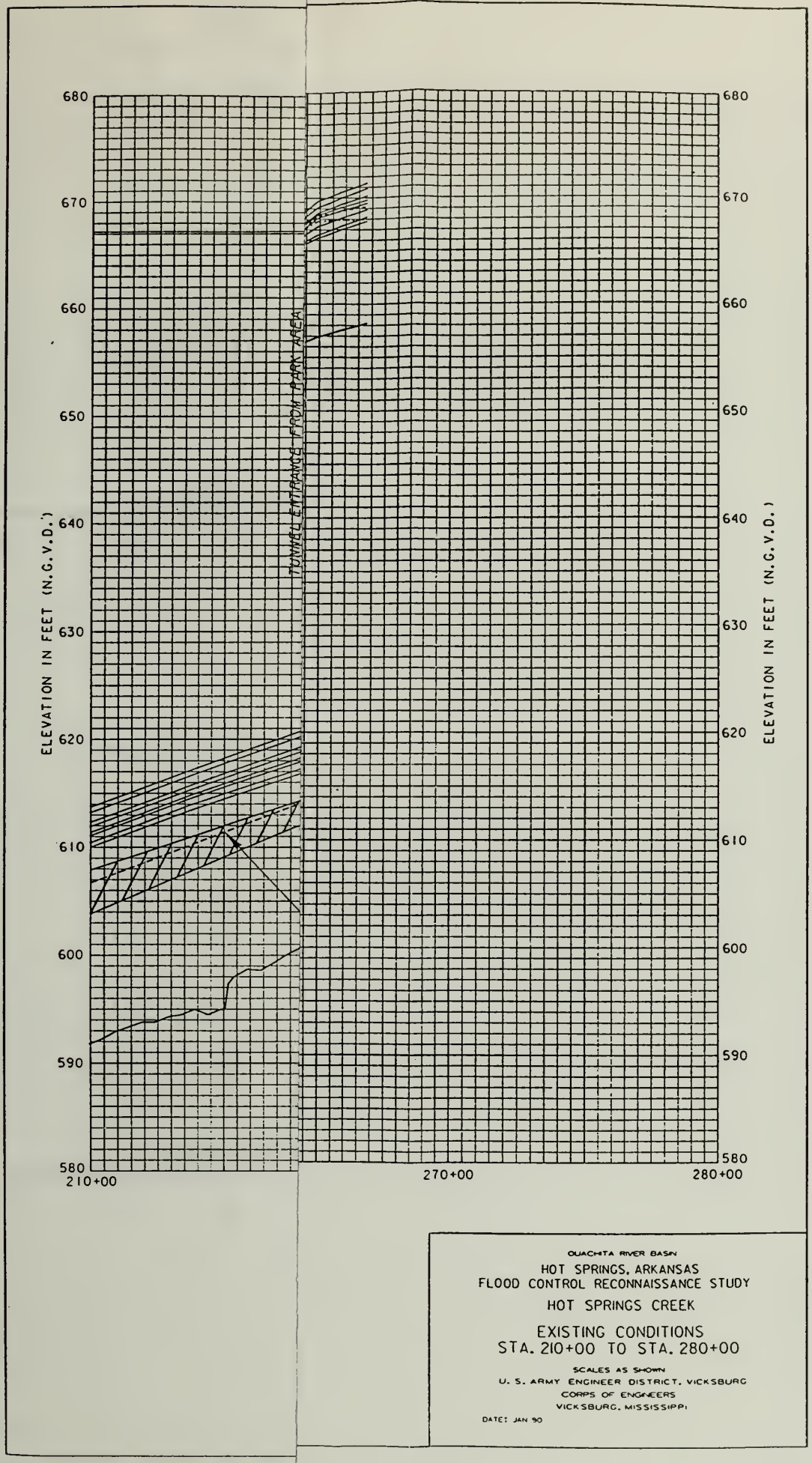
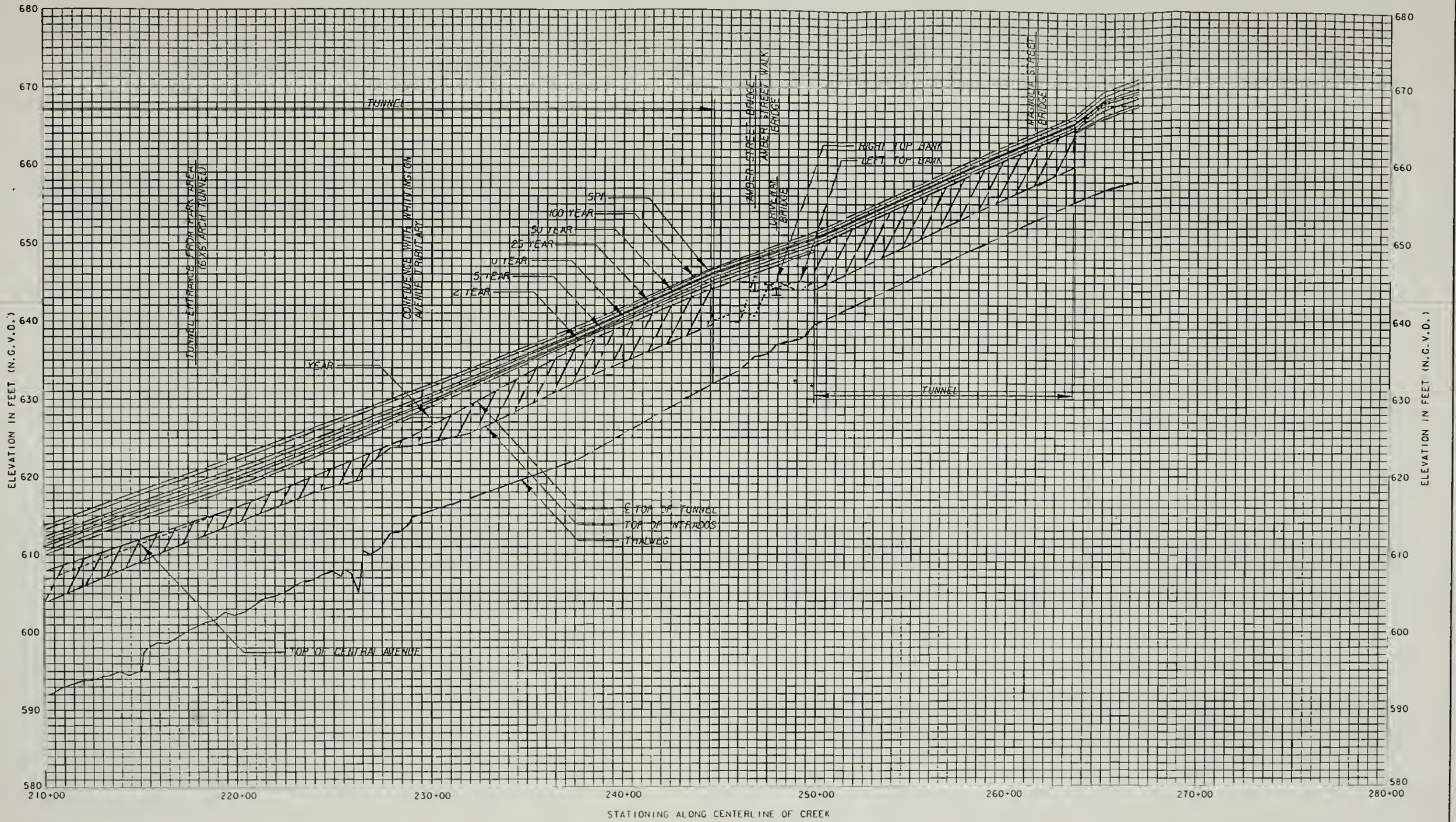


Figure 5 - Existing
(Corps of



OUACHITA RIVER BASIN
HOT SPRINGS, ARKANSAS
FLOOD CONTROL RECONNAISSANCE STUDY
HOT SPRINGS CREEK
EXISTING CONDITIONS
STA. 210+00 TO STA. 280+00
SCALES AS SHOWN
U. S. ARMY ENGINEER DISTRICT, VICKSBURG
CORPS OF ENGINEERS
VICKSBURG, MISSISSIPPI
DATE: JAN 90

Figure 5 - Existing Conditions Profiles for Hot Springs Creek, Station 210+00 to 240+00
(Corps of Engineers 1990 Reconnaissance Study)

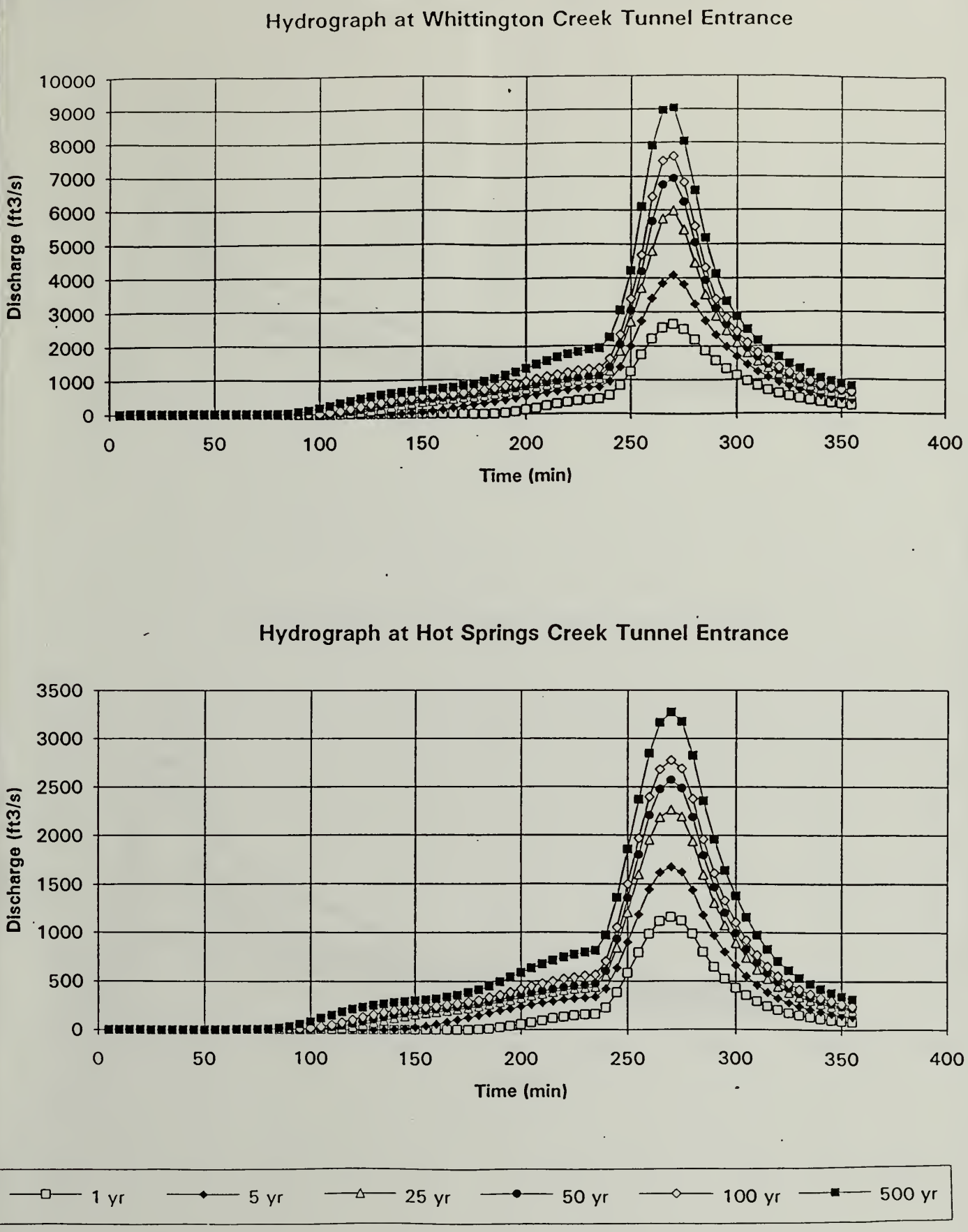
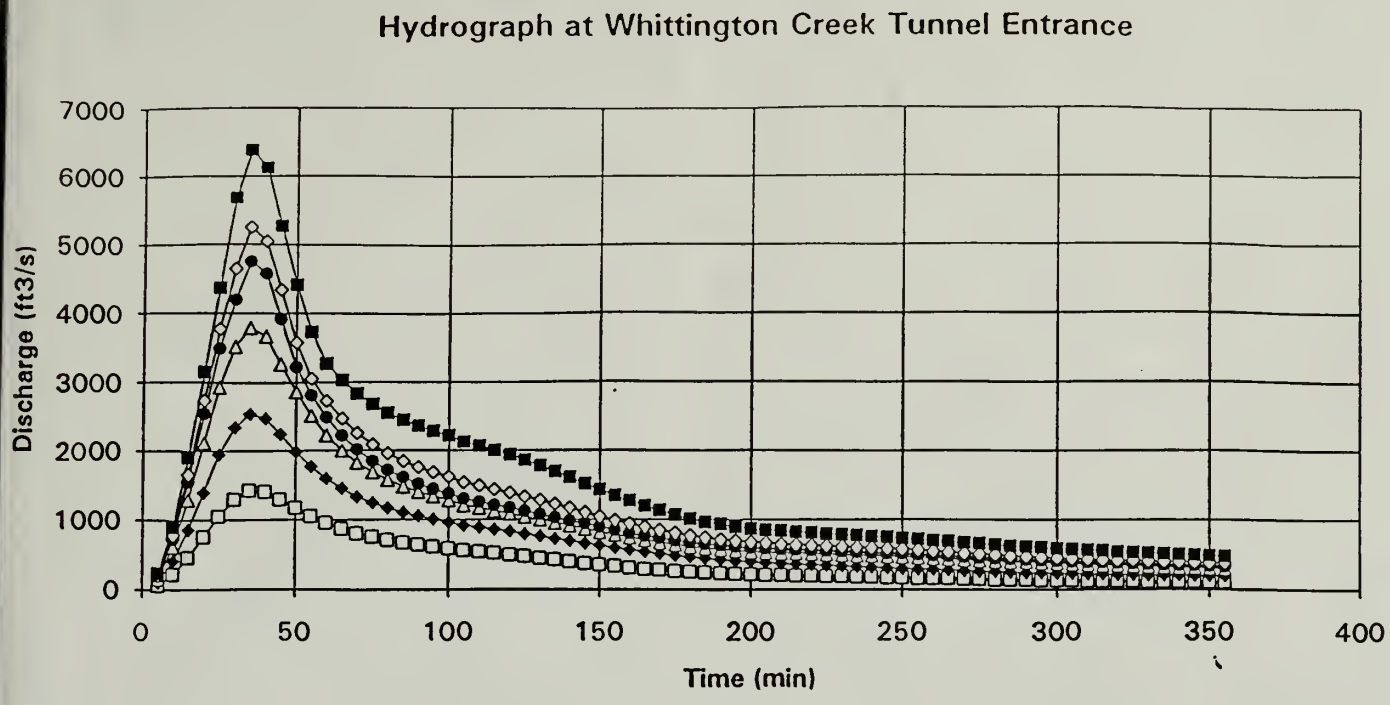


Figure 6 - Standard Distribution Rainfall Hydrographs at Hot Springs Creek and Whittington Creek Tunnel Entrances (COE Hydrology)



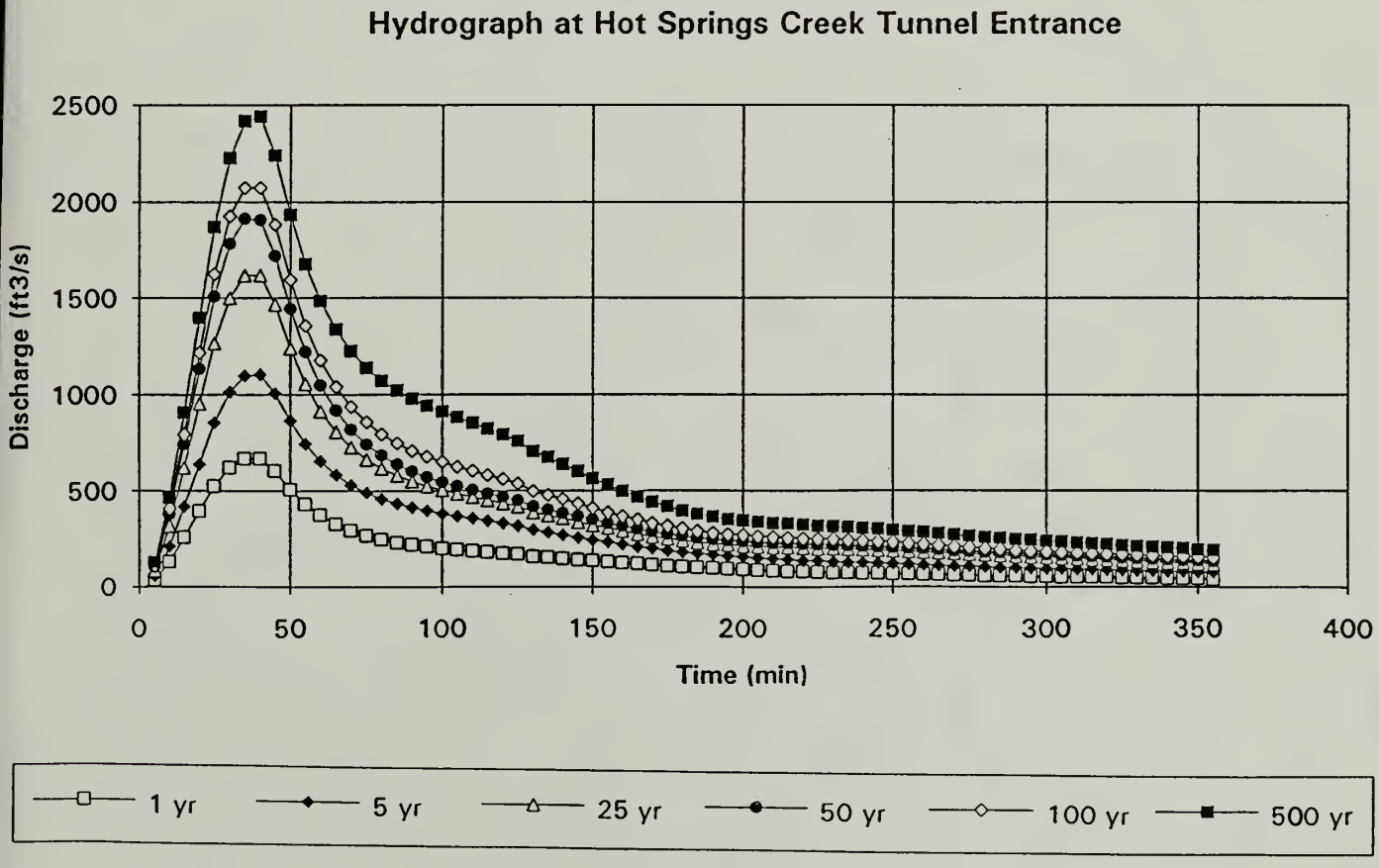


Figure 7 - - Front End Distribution Rainfall Hydrographs at Hot Springs Creek and Whittington Creek Tunnel Entrances (COE Hydrology)